Modeling Enzyme Kinetics Using the TI-83 Graphing Calculator

Derrick Goodwill

INTRODUCTION

Education in the twenty-first century is expanding in many new and exciting ways due to the impact of technology on our society. Modernized classroom utilize various multi-media formats to educate all students at primary and secondary levels previously available only to students in institutions of higher learning. Dissemination of this technology will produce more academically sound students better prepared to handle the challenges and rigors of college, graduate studies and beyond.

The process of learning in and of itself is not complicated; however, any classroom in America may contain students with several very unique learning styles at different ability levels. Each year educators provide instruction to convey their content area on level to the general class while addressing the above and below level students. Current advances in multi-media empowers educators by allowing them to tailor specific lesson plans to supplement the learning needs of all students in a classroom regardless of their ability level with respect to the content area. Learner-centered education is further enhanced by the use of technological resources. Student-driven assimilation of the content area is the goal of learner-centered education and multi-media assists the educator in achieving this goal by engaging more sensory learning modalities. This increases more on-task behavior leading to improved student learning.

Capturing and maintaining students' interest in the content area has been a major objective of educators for some time now. Using multi-media structured learner-centered environments can benefit educating "at-risk" students in addition to mainstream students. "At-risk" students enjoy learning exercises that allows them physical involvement and the ability to manipulate things with their hands. Merging of this instructional strategy with this specific instructional resource will mentally engage the "at-risk" students via the main three sensory learning modalities (auditory, tactile, and kinesthetic) thus prompting self-involvement in the learning activity. Thus, introduction and utilization of various forms of multi-media such as graphing calculators, computers, and other various interactive technological manipulatives should form the foundation of the educator's class activity within their lesson cycle.

Multi-media captures the student interest visually first, aurally second, and kinesthetically last. All three sensory learning modalities are utilized by integrating multiple disciplines; however, science instructors are implementing Texas Instrument–83 (TI-83) graphing calculator in a data collection capacity and the math instructors are teaching the students how to manipulate this data on the calculators. Integration of TI-83 graphing calculator into the classroom by Houston Urban-Learning Initiatives in a

Networked Community (HU-LINC) is currently underway in the Houston Independent School District (HISD). Our students will enjoy the benefits of possessing this knowledge prior to entering college. They will know how to collect data gathered from various probes, manipulate and transform it mathematically on a graphing calculator, a computer (spreadsheet), and eventually on a palm pilot (PDA). Students enjoy using manipulatives for many reasons but the ability for the student to handle and operate the teaching instrument ranks very high; and we will use this interest to develop long lasting interest in scientific edification.

BACKGROUND

Special curriculums have been created to address the particular needs of students appearing more than one standard deviation above and below the mean on the bell curve. However, this curriculum unit was created to promote interest in science of the average student classified as "at-risk." Math and science (disciplines requiring a certain depth of concentration, focus, and analytical thinking) are two subjects which do not readily appeal to the at-risk student primarily due to the high level of mental focus and task commitment required. Nevertheless, educators must develop teaching strategies directed towards addressing the particular needs of at-risk students in math and science.

Classification of a student as at-risk does not and should not equate with low-academic potential. In many instances, at-risk students' academic performance may fall within the low performance or even failing range in some instances; however, in some cases their academic record reflects low task commitment more rather than academic ability. One strong indicator of this phenomenon reveals itself during the review of the TAAS results; where the so-called at-risk student either passes all parts of the Stanford 9 and/or TAAS tests or even gains academic excellence, despite a lack of participation in class work, homework, projects, and/or testing.

At-risk students generally lack the ability to initiate, sustain, and complete the learning process. In a more general sense, these students' task commitment teeters on the low-end of acceptability. I define these kids as belonging to the "Polaroid Generation." The Polaroid Generation refers to a particular type of student with a very low Emotional Quotient (EQ) irrespective of their Intelligence Quotient (IQ). Unlike the IQ test, the EQ test measures the ability of a person to defer gratification instead of measuring the fund of knowledge of the person. The EQ test shows a stronger correlation to a person's success in life as an adult than the IQ test. Unfortunately, standardized testing dominates as the primary method of evaluating a student's progress.

Students whom I include within the Polaroid Generation display certain characteristics demonstrative of low levels of maturity within their age group. The concept of the Polaroid Generation is derived from my experiences with my Polaroid camera. The Polaroid camera's claim to fame extends from its capacity to generate a picture on demand within minutes. The behavior of youth of today reflects this

increasingly impatient trend, which seeks and expects grandiose rewards with minimal to zero effort input. In the classroom this mentality expresses itself when students place greater emphasis on the grade obtained in the class instead of placing this emphasis on developing the student's competence level in the respective educational discipline.

As we progress further into the Information Age within America, we are becoming a nation who wants and expects everything to occur at this very instance and to our very own whim. Instant gratification without any effort; we do not care how we get what we want…we just want it, now! Unfortunately, a good education is something one must earn and it truly begins after high school. Acquiring one requires a modicum of dedication and perseverance in addition to the development of critical thinking skills. Nonetheless, the educational system is falling behind in its attempt to meet the needs of the at-risk students as evident in the increasing number of students repeating their high school freshman year and the concurrent decrease in the matriculation rate from high school in general.

This problem translates directly into difficulties with the presentation of the science content via direct instruction. Another feature common to the Polaroid Generation is the microwave-like attention span. Once engaged in a project with a problem to solve these students will work extremely hard for short periods; then they will stop. If they reach an impasse they will let their frustration levels dominate them resulting in immediate abandonment of the current assignment. Sometimes extending deadlines work and in other cases it does not. Next, at-risk students will spend more energy on securing an answer – for some, any answer – from a neighboring peer rather than trying to determine a solution to the problem for them. Low attention levels of at-risk students increase the off-task time for themselves and the surrounding peer population regardless of the academic capability of students involved.

The majority of the student population from M.C. Williams Middle School (HISD) is from economically and socially disadvantaged households. Many of our at-risk students face tremendous challenges unknown to prior generations just ten years ago. Some of the current problems faced by the educational system stems directly from the unusual circumstances present in the at-risk student population. For example, is it unrealistic to expect a student to focus on learning content mastery in each discipline when this same student must fend for him/herself, outside the school environment, due to the absence of proper parental involvement and/or no support or guidance from the extended family either? For many students, immediate survival on a day-to-day basis is definitely prioritized over reaching any long-term educational goals (which require stable environments) such as completing the high school curriculum and matriculating into an institution of higher learning. Premature exposure to the hash realities of life at an increasing young age takes a toll on these students and negatively impacts the ability of the at-risk students to succeed most poignantly in secondary and more recently in the primary educational arena. The influence of these negative factors severely hinders their present and future academic and social achievements.

In the process of addressing the non-academic needs of at-risk students, public school system systems must responded seriously by instituting new and creative support mechanisms aimed at meeting the non-academic needs, as needed, in an effort to raise the matriculation rate of this population of students. However, at present, a large gap exists between what each particular at-risk student needs to ensure his or her academic success in the modern classroom still exists. It is this critical juncture where the instructional teacher can help lessen the negative factors, accentuate the positive factors imposed on the at-risk students, and narrow the educational deficiencies. In doing so, we lessen this gap by increasing their competence in their respective discipline. In providing creative instruction aimed primarily to capture, sustain, and invoke critical thinking skills (analysis, synthesis, and evaluation) while engendering self-directed learning educators give the tools essential to bridging the educational gap for the at-risk students; thus empowering them with the ability realize their academic dreams now with assistance and in the future alone.

TEACHING APPROACHES

Teaching at-risk students the fundamentals enabling them to succeed in our nation's institutions of higher learning is the task. Traditional science and non-science pedagogy unfortunately does not capture enough of the learning interest of the at-risk students, in addition to some of the mainstream students likewise. New and more innovative teaching methods must be explored and implemented into each classroom. In order to achieve this goal, educators must connect mentally with all students in a profound way through the three major sensory modalities. Educating our students within the backdrop of current technology is the perfect means of capturing the sincere interest of the at-risk students' attention and redirecting it towards mastering the objectives at hand. Current technological advances in areas of software and hardware affords today's primary and secondary students the opportunity to develop their computing skills previously privileged only to undergraduate and graduate students.

Changing the current popular method of teaching science by formally introducing the content theory followed by performing various experiments in a laboratory setting to its inverse will assist in capturing the attention of the at-risk students. Many at-risk students are simply bored with traditional teaching methods due to numerous reasons, hinting towards apathy-related boredom. Inversing the presentation of the same information will contribute to increasing content retention. As stated before, at-risk students sometimes have lower attention spans than mainstream students and find difficulty in maintaining focus in a classroom setting requiring increased levels of analytical thought. Varying the learning modes can exert an influence on any student's attention span ultimately impacting their ascent on the learning curve upwardly. Children by nature are explorative and thus enjoy learning about the world around them kinesthetically. Thus, beginning with the laboratory exercise instead of the theory should assist in capturing the interest of the at-risk students and others who enjoy moving while learning.

Active participation by the at-risk student gives them the opportunity to explore and learn on their own terms and in their own learning mode. Independence with respect to learning allows students to see themselves as a part of the educational process instead of an institutionalized victim of the educational process. Too many times we expect students to absorb and organize information in the fashion we were taught. Educators sometimes revert to primitive low-level teaching styles because it enables them to guide and check large numbers of students' progress quickly. Unfortunately, this method of teaching dampens the student's ability to learn and does not challenge them to grow.

For example, instead of explaining the scientific basis and mathematical theory behind acids and bases, an educator can teach these same concepts to secondary students by giving the students pH probes and the TI–83 graphing calculators and asking them to measure some common household items first. Next, the educator can give the cooperative learning groups a series of laboratory exercises designed to generate sufficient data to create a science report. After assisting the students develop their reports, the educators can now present the theory to the students explaining the observations of the laboratory exercises, check for mastery, adjust, reteach, extend where necessary, and close the lesson.

In following protocol, the student is afforded the opportunity for self-exploration in the laboratory setting and in the lecture setting. Capturing of their interest sincerely should produce a flow of questions from our students indicative of their inquisitive side. The TI–83 graphing calculators engages the student kinesthetically and visually, thus providing something for them to manipulate and see concurrently. The calculators produce certain sounds, thus a minor form of auditory stimulation occurs too. As one can see, this technique captures the student's interest from a right brain approach. From this critical point, segue to the lecture introducing the theory to the students as a means of providing the logical reasoning directing the observed controlled laboratory phenomena captures the student's interest from the left side of the brain. The latter represents auditory stimulation and the most popular method of instruction in our institutions of higher learning. Educators must use any method successful in their classroom to convey the content; however, preparing the students for success at the next level will depend on conveying content via a left-brain approach to the secondary student.

As stated earlier changing the sequence of the teaching strategy leads the at-risk student to participate more in the learning process of his/her own accord by encouraging him/her to look within themselves first for answers and then secondly look outside of him/herself (towards the educator) for resolution(s). Self-induced learning as exemplified in "Learner-centered" education places the onus of learning on the student through his/her own free will. The old axiom of leading the horse to the water but being unable to make it drink exemplifies our current situation; yet, this is circumvented by with the old carrot or sugar cube remedy. Educators must convince the horse prior to seeing the trough that it is truly thirsty and needs to draw from the wisdom of their knowledge. Therefore constructive kinesthetic and visual enticement followed by auditory and visual

reinforcement should solidify an intergraded mental correlation between the laboratory exercise and its supporting theory. This kind of experience should create points of references for at-risk students to build a solid educational base to move forward in life and expand upon.

ENZYME KINETICS

Mixing chemicals (reactants) together under the proper condition elicits the creation of newly formed products. Thousands of reactions involving enormous enzymes occur in the human body contributing to maintaining homeostasis, and thus life, every single minute. Many of these reactions would not occur under standard or normal conditions. However, various catalysts assist increasing the velocity of these reactions thereby increasing the efficiency of the chemical reactions occurring the human body.

Velocity of a reaction alludes to the speed of its reaction. Speed is a terminology referring to the distance traveled divided by the time it takes traverse that distance. Simply stated, speed is the change in distance associated with a change in time. Speed is one form of rate. In chemistry, we do not use the terminology referenced as speed because we are not measuring this kind of change. The kind of change measured in a chemistry lab is termed the reaction rate. As reactants are mixed, they undergo chemical changes to produce new substances. Chemists measure these kinds of conversions.

Conceptually speed and reaction rate are akin to each other; however, they denote two different phenomena in science. Take for example, two moving cars referred to as car #1 and car #2 traversing a certain distance (50 miles) between point A and point B. The speed or rate is represented by the time it takes for each car to pass from point A to point B. Each car travels at different rates (speed). Car #1 covers the distance between points A and B in one hour, whereas, car #2 covers this distance in two hours. Thus car #1 and car #2 have different speeds and thus different travel rates. Car #1 moves at a speed of 50 mph while car #2 moves at a speed of 25 mph. Like the two different cars, different chemical reactions occur or proceed at varying rates also. Reaction rates of chemical reactions focus on the conversion of reactants into products and/or vice versa (William, 532).

Reaction rates in living organisms are critical to their survival. Hindering reaction rates can literally determine whether a living organism can respond quickly enough to avoid death. In order for a chemical reaction to occur the reactants must meet certain qualifications. Every chemical reaction must posses enough energy to pass through the transition state in order to form the products. Spontaneous reactions are the reactions in possession of the activation energy required to completely transform the reactants into products without any thermal or kinetic input from an outside source. These reactions are usually exothermic in nature additionally.

Creation of the new substances from the initial substrates requires achieving several conditions first. Satisfaction of the following conditions permits a chemical reaction to proceed to resolution. First, the thermal (kinetic) energy of each participating particle must be greater than the energy of activation. Each particle must contribute some kinetic energy to the formation of the activated complex to raise the overall kinetic energy above that of the energy of the initial reactants prior to mixing. In doing so, the overall kinetic energy of the activated complexes meet or exceed the energy of activation. At this point, the activated complexes must meet two more additional conditions.

Secondly, each activated complex must have the proper orientation at the moment of collision with another sufficiently energized activated complex. Ideal orientation of the sufficiently activated complexes at the moment of collision permits meshing of the respective valence electrons needed to weaken the initial reactant bonds (Davis, 553). Improper impact orientation of the each molecule prevents bond disruption leading to repulsion of one molecule by the other (533). Nevertheless, two or more properly energized, orientated activated complexes must meet one final condition.

The last and final condition required for transformation of reactants into products is effective collision (533). The thermal energy locked in the bonds of the activated complexes exceeding the energy of activation sufficiently dissolve and form new bonds (533). As the new product bonds are formed, the activated complex de-energizes by expelling the excess kinetic energy in its thermal form. One can now appreciate why most spontaneous chemical reactions are exothermic in nature.

Four main factors affecting reaction rates are temperature, concentration, particle size, and catalyst (William, 536). Chemical kinetics is the study of reaction rates and its reaction mechanisms of chemical reactions. This field of chemistry concerns itself with the various factors influencing the change in the concentration of reactants per unit time.

Increasing the temperature of a closed system containing a chemical reaction increases the reaction rate significantly. Likewise, the contra positive decreases the reaction rate. Referring to the collision theory discussed above provides the reasoning for this finding. Each activated complex requires a defined quantum of kinetic or thermal energy equal to or greater than the activation energy necessary to break the reactant bonds in preparation for forming the product bonds. An increase in thermal energy yields an increase in kinetic activity for each particle thereby increasing the particle collision frequency leading to an increase in product formation. Beginning near room temperature, the reaction rates of many common reactions roughly double with each 10 K rise in temperature (Davis, 539).

Increased concentration of reactants for the forward reaction or products for the reverse reactions increases the reaction rate, also. Again, the collision theory provides the rationale for this observation too. Higher concentrations of substrates lead to increased collision frequency. Like temperature, increased collision frequency of properly

energized and orientated activated complexes results in more product formation through dissolution and formation of reactant and product bonds. This basic concept is conveyed to young science students with the burning candle experiment. A short candle is burned producing a small flame in an open system with an unlimited supply of oxygen (less than 20%) via the air. Next, the instructor burns the same candle but this time the system is closed restricting the supply of oxygen. Eventually, the oxygen in the system dissipates and the combustion reaction with oxygen is unable to proceed further resulting in extinguishing the small flame. Conversely, supplying a closed system with pure oxygen (100%) enables the combustion reaction to proceed at a higher than normal rate yielding a larger flame initially; however, the flame ceases once the oxygen molecules are consumed in the combustion process.

Most chemical reactions proceed at a slow rate; however, addition of a catalyst greatly increases the reaction rate. A catalyst is a substance that changes the reaction rate of a chemical reaction but it itself is not consumed or destroyed in the reaction and retains its identity at completion of the reaction. In a chemical equation the catalyst is placed over the yield sign signifying its distinction from the both the reactants and the products. Decreasing the activation energy for any chemical reaction results in an increased reaction rate and product formation. One speculation about the reason for the efficacy of catalysts suggests the formation of an alternative activation-complex that follows a significantly lower activation energy pathway (Davis, 540).

Most catalysts are metals and only very small amounts are necessary to increase reaction rates tremendously. Catalysts are extremely important to human biochemistry and responsible for thousands of reactions occurring daily which are impossible under normal conditions. Inhibitors are substances capable of negating the effects of catalysts. Presence of an inhibitor can decrease the "speed" or reaction rate of a chemical reaction thus counteracting the effects of the catalyst. In some instances, it is possible for an inhibitor to completely cancel out the catalyst's effect on the reaction rate. This mechanism is the basis behind why poisons works. Snakes inject their prey with venom aimed at disrupting critical biochemical reactions thus making them more susceptible to attack.

Maximum surface area allowing the greatest contact occurs between reactants is ideal as appreciated in homogeneous reactions (involving two fluid phases). Under these conditions, reactants and catalytic particles interact with high degrees of contact. On the other hand, heterogeneous reactions (between fluid phases and solid phases), depending on the presentation of the solid phase, displays large variations in its influence on reaction rates. Consider the catalytic role of Platinum in producing water from elemental hydrogen and oxygen at room temperature. Placing one cm^3 unit of platinum will increase this chemical reaction rate significantly via the aforementioned alternative activated-complex.

Placing ten one mm^3 units of platinum in this same chemical reaction will increase the reaction rate even further than the first scenario. However, placing a pulverized powder version of platinum equal to the mass of the platinum in the second scenario will increase the reaction rate even more significantly. This last scenario represents the increased surface area ratio of the catalyst to the reactants providing the maximum amount of interaction between the catalyst and the activated complexes within solution. This phenomenon represents basic colligative property where the enhanced reaction rate increases directly proportionally to the increased particle-to-particle interactions.

In chemistry, any basic reaction can proceed in one of two directions. The chemical equation below shows the products C and D created from the reactants A and B. The forward direction is defined as the combining of substances A and B (synthesis) to create two newly formed substances C and D. The reverse reaction proceeds in the opposite direction where the products C and D decompose back into the reactants A and B.

Reversible reactions are capable of proceeding in the forward and the reverse direction simultaneously (see below). However, non-reversible reactions are incapable of decomposing back into the original reactants. Some reactions are impossible. For example, applying heat or flame to a piece of paper will cause the paper to burn until ash is formed. Creation of a new substance, the ash (the product), signifies a chemical change by the change in the physical properties possessed originally by the paper; however, ash cannot convert back into paper.

$$aA + bB \leftrightarrow cC + dD$$
(reversible reaction)

$$eE + fF \rightarrow gG + hH$$
(non-reversible reaction)

As mentioned earlier, reaction rates for specific chemical reactions differ according to the particular involved chemicals in question. In a reversible reaction, the reaction rates for the forward reaction and the reverse reaction usually differ as each reaction occurs simultaneously.

Once substrate interactions begin, the chemical reaction will proceed towards completion. When considering irreversible reactions/processes, all of the reactants convert themselves into products via the forward reaction solely. Irreversible reactions do not have a reverse reaction, thus these kinds of chemical reactions do not achieve a state of equilibrium. Irreversible reactions only proceed towards conversion to the products. Reversible reactions, on the other hand, have both a forward and reverse reactions where the reactants are converted to products and products are converted to reactants simultaneously.

Co-ocurrent exchange between the formation and/or disassociation of the products and the reactants establishes a dynamic-state with respect to equilibrium. Each chemical reaction determines its own equilibrium state based on the reaction rates of both the forward and reverse reactions. Forward and reverse reaction rates are usually different thus; either the reactants or the products are favored once equilibrium is reached. In our example below, three short arrows represent a predominance of the products over the reactants. This signifies the rate of the forward reaction is greater than the rate of the reverse reaction. Normally, two arrows are used and the longer arrow represents which side of the equation predominates.

$$aA + bB \leftarrow\rightarrow\rightarrow\rightarrow cC + dD$$
(a basic chemical reaction)

The equilibrium, K_{eq}, is a valued derived from multiplying all the products of the reaction raised by their coefficients then dividing that value by multiplying all the reactants of the reaction raised by their coefficients. The formula for the equilibrium constant is written below.

$$K_{eq} = [C]^c \times [D]^d / [A]^a \times [B]^b$$
(equilibrium formula based on basic chemical reaction)

Thus, a numerical value is derived from which chemists are capable of assessing pertinent information from. If the forward and reverse reaction rates of a chemical reaction were equal, then K_{eq} would equal one (=1). This implies equity in the amount of products and reactants once the reactions reaches equilibrium suggesting the forward reaction rate matches the reverse reaction rate. When the forward reaction predominates over the reverse reaction the K_{eq} value is greater than one (>1) indicating more products existing at the state of equilibrium. Likewise, the contra positive position, where the K_{eq} is less than one (<1) indicating more reactants present at equilibrium. Equilibrium constants for any given reversible reaction, within a closed system, do not change unless the conditions of the enclosed system are changed.

$K_{eq} = 1$, neither products nor reactants favored at equilibrium
$K_{eq} > 1$, products favored at equilibrium
$K_{eq} < 1$, reactions favored at equilibrium

Changing the conditions of a closed system will impact its K_{eq} either positively or negatively thus changing its numerical value. As such, the new conditions will again seek a new equilibrium "set point." The chemical reaction's new "set point" will be determined by the "changed conditions." In chemistry, the principle explaining this phenomenon is called Le Chatelier's Principle. Le Chatelier's Principle stipulates that a dynamic system changes in response to stresses imposed upon it. By definition, this principle applies only to reversible reactions. The reversible reaction adjusts itself according the type of stress imposed on it. Generally, the following stresses are capable

of evoking change in the equilibrium constant: 1-concentration (of reactants), pressure, and temperature (Davis, 562-64).

According to Le Chatelier's Principle, a chemical reaction will readjust itself to relieve the stress by forcing the chemical equation away from the side of the equation to the stress is applied (William, 541). Considering the specific example (below) of the synthesis of ammonia, introducing more nitrogen and/or hydrogen (reactants) changes the initial conditions of the system. The disturbed system responds to the left-sided stress by creating more ammonia (product). Conversely, introducing more ammonia, on the right side of the equation, will promote its decomposition to elemental nitrogen and hydrogen. Thus allowing the system to relieve the stress imposed upon it. With respect to the non-specific example below, increasing or decreasing pressure or heat on either side of the chemical equation will shift the reaction to the opposite side of the arrow shifting some of the pressure away from its point of origin.

$$N_2\,(g) + 3H_2\,(g) \leftrightarrow 2\,NH_3\,(g)$$
(specific example)

(+/-)Pressure (+/-) Heat + reactants $\leftrightarrow$ products (+/-) Heat (+/-) Pressure
(non-specific example)

As previously shown, the speed at which a chemical reaction proceeds can critically impact the survivability of a living organism. Biochemical reaction rates within an organism must function unhampered in order for the organism to respond and interact with the environment and its stressors successfully. Thus learning enzyme kinetics is essential for secondary students preparing to enter undergraduate and graduate studies in the field of science.

As one can see, understanding the concepts explaining how reaction rates determine and influence enzyme kinetics is no longer relegated to upper level high school chemistry courses or institutions of higher learning. Any science concepts, no matter how complex it may seem, is teachable at the middle school level when the lesson cycle is properly planned and supported by the right technological resources. Complex ideas such as reaction rates inside of enzyme kinetics do not seem so lofty when correlated to a simpler idea more familiar to the secondary student. Early introduction to advanced science and mathematics knowledge affords students the opportunity and time to develop a deeper grasp of these content areas inevitably better preparing them for matriculation to college studies.

TEKS:

2C

The student uses scientific methods during field and laboratory investigations. The student is expected to express and manipulate chemical quantities using

scientific conventions and mathematical procedures such as dimensional analysis, scientific notation, and significant figures.

11B

The student knows that balanced chemical equations are used to interpret and describe the interactions of matter. The student is expected to demonstrate the use of symbols, formulas, and equations in describing interactions of matter such as chemicals and nuclear reactions

13C

Student knows relationship among the concentration, electrical conductivity, and colligative properties of a solution. The student is expected to measure and compare the rates of reaction of solid reactant in solutions of varying concentration.

15B

Student knows factors involved in chemical reactions. The student is expected to relate the rate of a chemical reaction to temperature, concentration, surface area, and presence of a catalyst.

LESSON PLAN ONE

Toothpick Biochemistry: Experiments with Enzyme Kinetics

Objectives

Students will:

- Determine the limitations imposed on the rate of reactions.

Introduction

Without enzymes, the sun wouldn't shine, the earth wouldn't spin, and all biochemical processes would slowly stop. Actually, the solar system would be fine but life, as we know it would not be. Here is a pair of activities designed to demonstrate some important relationships governing enzyme activity.

Materials

Wooden toothpicks (approximately 250)
Paper clips (preferably "giant" size)
Shallow dish or bowl
Graph paper
Watch with a second hand
Blindfold (optional)

Pre-Lab

1. Part A, “Rate of Product Formation,” is most easily done in groups of three students. Each group will need 90 toothpicks and the activity will take about five minutes.

2. Part B, “Reaction Rate vs. Substrate Concentration,” can be done in groups of two or three students. You may wish to assign each group a separate initial concentration (requiring at least ten groups) and pool data, or each group can conduct the entire concentration series-time permitting. To conduct the entire series, each group will need 180-200 toothpicks.

Procedure

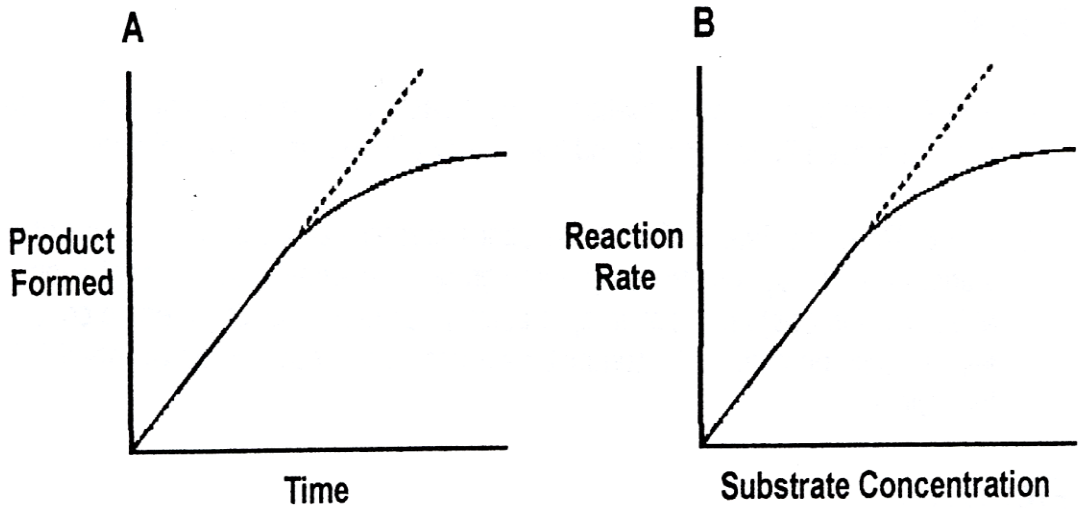
Part A: Rate of Product Formation

1. Place 90 to 100 wooden toothpicks in a shallow bowl. The toothpicks represent the reactive substrate in this reaction.
2. In a group of three, one person will be the timer, one will record the data, and the third will be the "enzyme.” The enzyme functions by snapping toothpicks in half using thumb, index finger, and middle finger. The enzyme does this without looking, and all products" (broken toothpicks) remain in the bowl.
3. The experiment is conducted in 20-second intervals. The timer (the instructor can play this role if students are working in pairs) calls out "start,” and then audibly marks each 20-second interval. The recorder tallies the cumulative number of toothpicks broken as each interval is called out. A minimum of fourteen data points should be tallied.
4. Graph the results by plotting *Product Formed* (the total number of toothpicks broken) *vs. Time* (20 seconds, 40 seconds, etc.)

Part B: Reaction Rate vs. Substrate Concentration

1. Place 80 to 100 paper clips in the bowl. The paper clips represent a "solvent" in which the toothpicks are "dissolved.” Different concentrations are simulated by mixing different numbers of toothpicks in with the paper clips.
2. For the first trial, place 10 toothpicks in the bowl with the paper clips. The enzyme has 20 seconds to "react" (break as many toothpicks as possible). Record the number broken at a concentration of ten.
3. Remove broken toothpicks and repeat with concentrations of 20, 30, and 40, up to at least 100 toothpicks. Generate at least ten data points.
4. Graph the results by plotting *Reaction Rate* (toothpicks broken in 20 seconds) *vs. Substrate Concentration* (10, 20...).

Discussion



The resuming graphs should resemble those depicted above for Parts A and B. In Part A, the initial rate of product formation will be fairly constant for the first two or three minutes-the initial rate (the dashed line) being approximately twenty-five toothpicks broken per minute. During this period, the ratio of unbroken to broken toothpicks is fairly high and the rate is determined by the efficiency (manual dexterity) of the enzyme. As this ratio decreases, the enzyme spends more and more time searching for unreacted substrate (unbroken toothpicks) and, as a result, the rate steadily decreases until all toothpicks have reacted or the experiment is stopped.

Part B adds the variable of concentration-in this case, the concentration of toothpicks in a paper clip "solution." With the enzyme concentration constant, the rate will initially increase proportionally to the substrate concentration-which should be evident up to a concentration of sixty or seventy toothpicks. Beyond that, the rate increases more and more slowly until a rate maximum is reached-there is a physical limit to how fast the enzyme can react with the toothpicks. At high substrate concentrations, the enzyme becomes saturated with substrate. At this point, the limiting factors are the speed with which the enzyme and the substrate can combine and react (efficiency), and the concentration of the enzyme. To increase the reaction rate further would require either Superman (faster fingers), or higher enzyme concentration (more fingers in the bowl).

References

Green, N.P.0.; G.W. Stout; D.J. Taylor. *Biological Science I: Organisms, Energy and Environment*. Cambridge, England: Cambridge University, 1990; pp. 172-73.

Acknowledgement

Special thanks to Mrs. Taylor James, Graham High School, Graham, Texas, for providing the basis for this activity.

LESSON PLAN TWO

Chemical Equilibrium: Finding a Constant, K_c

Objectives
Student will:

- Predict changes in the equilibrium position due to changes in concentration, temperature, and pressure; and
- Determine the equilibrium constant, Kc, of a chemical equation.

The purpose of this lab is to experimentally determine the equilibrium constant, K_c, for the following chemical reaction:

$$Fe^{3+}\ (aq) + SCN^{-}\ (aq) \rightarrow FeSCN^{2+}\ (aq)$$
$$\text{Iron (III) + thiocyanate} \rightarrow \text{thiocyanoiron (III)}$$

When Fe^{3+} and SCN^{-} are combined, equilibrium is established between these two ions and the $FeSCN^{2+}$ ion. In order to calculate K_c for the reaction, it is necessary to know the concentrations of all ions at equilibrium: $[FeSCN^{2+}]_{eq}$, $[SCN^{-}]_{eq}$, and $[Fe^{3+}]_{eq}$. You will prepare four equilibrium systems containing different concentrations of these three ions. The equilibrium concentrations of the three ions will then be experimentally determined. These values will be substituted into the equilibrium constant expression to see if K_c is indeed constant.

In order to determine $[FeSCN^{2+}]_{eq}$, you will use the Colorimeter shown in Figure 1. The $FeSCN^{2+}$ ion produces solutions with a red color. Because the red solutions absorb blue light very well, the blue LED setting on the Colorimeter is used. The computer-interfaced Colorimeter measures the amount of blue light absorbed by the colored solutions (absorbance, A). By comparing the absorbance of each equilibrium system, A_{eq}, to the absorbance of a *standard* solution, A_{std}, you can determine $[FeSCN^{2+}]_{eq}$. The standard solution has a known $FeSCN^{2+}$ concentration.

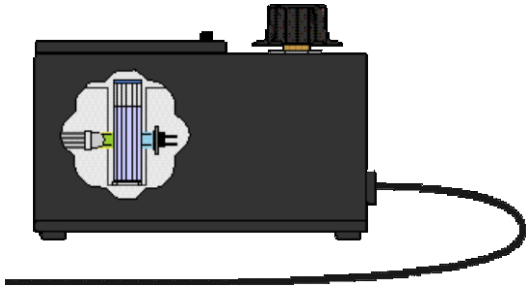


Figure 1

To prepare the standard solution, a very large concentration of Fe^{3+} will be added to a small initial concentration of SCN^{-} (hereafter referred to as $[SCN^{-}]_i$. The $[Fe^{3+}]$ in the

standard solution is 100 times larger than $[Fe^{3+}]$ in the equilibrium mixtures. According to LeChatelier's principle, this high concentration forces the reaction far to the right, using up nearly 100% of the SCN^- ions. According to the balanced equation, for every one mole of SCN^- reacted, one mole of $FeSCN^{2+}$ is produced. Thus $[FeSCN^{2+}]_{std}$ is assumed equal to $[SCN^-]_i$.

Assuming $[FeSCN^{2+}]$ and absorbance are related directly (Beer's Law), the concentration of $FeSCN^{2+}$ for any of the equilibrium systems can be found by:

$$[FeSCN^{2+}]_{eq} = \frac{A_{eq}}{A_{std}} \times [FeSCN^{2+}]_{std}$$

Knowing the $[FeSCN^{2+}]_{eq}$ allows you to determine the concentrations of the other two ions at equilibrium. For each mole of $FeSCN^{2+}$ ions produced, one less mole of Fe^{3+} ions will be found in the solution (see the 1:1 ratio of coefficients in the equation on the previous page). The $[Fe^{3+}]$ can be determined by:

$$[Fe^{3+}]_{eq} = [Fe^{3+}]_i - [FeSCN^{2+}]_{eq}$$

Because one mole of SCN^- is used up for each mole of $FeSCN^{2+}$ ions produced, $[SCN^-]_{eq}$ can be determined by:

$$[SCN^-]_{eq} = [SCN^-]_i - [FeSCN^{2+}]_{eq}$$

Knowing the values of $[Fe^{3+}]_{eq}$, $[SCN^-]_{eq}$, and $[FeSCN^{2+}]_{eq}$, you can now calculate the value of K_c, the equilibrium constant.

Materials

Power Macintosh or Windows PC
Vernier computer interface
Logger*Pro*
Vernier Colorimeter
1 plastic cuvette
five 20 x 150 mm test tubes
thermometer
0.0020 M KSCN
0.0020 M $Fe(NO_3)_3$ (in 1.0 M HNO_3)
0.200 M $Fe(NO_3)_3$ (in 1.0 M HNO_3)
four pipets
pipet bulb or pipet pump
three 100-mL beakers
tissues (preferably lint-free)

Procedure

1. Obtain and wear goggles.
2. Label four 20 x 150 mm test tubes 1-4. Pour about 30 mL of 0.0020 M $Fe(NO_3)_3$ into a clean, dry 100-mL beaker. Pipet 5.0 mL of this solution into each of the four labeled test tubes. Use a pipet pump or bulb to pipet all solutions. **CAUTION:** *$Fe(NO_3)_3$ solutions in this experiment are prepared in 1.0 M HNO_3 and should be handled with care.* Pour about 25 mL of the 0.0020 M KSCN into another clean, dry 100-mL beaker. Pipet 2, 3, 4 and 5 mL of this solution into Test Tubes 1-4, respectively. Obtain about 25 mL of distilled water in a 100-mL beaker. Then pipet 3, 2, 1 and 0 mL of distilled water into Test Tubes 1-4, respectively, to bring the total volume of each test tube to 10 mL. Mix each solution *thoroughly* with a stirring rod. Be sure to clean and dry the stirring rod after each mixing. Measure and record the temperature

of one of the above solutions to use as the temperature for the equilibrium constant, K_c. Volumes added to each test tube are summarized below:

Test Tube Number	$Fe(NO_3)_3$ (mL)	KSCN (mL)	H_2O (mL)
1	5	2	3
2	5	3	2
3	5	4	1
4	5	5	0

3. Prepare a standard solution of $FeSCN^{2+}$ by pipetting 18 mL of 0.200 M $Fe(NO_3)_3$ into a 20 x 150 mm test tube labeled "5." Pipet 2 mL of 0.0020 M KSCN into the same test tube. Stir thoroughly.
4. Prepare the computer for data collection by opening the file in the Experiment 20 folder of *Chemistry with Computers*. You should see a live Meter window to display absorbance, and a Table window with columns for the trial number and the absorbance value.
5. Prepare a *blank* by filling a cuvette 3/4 full with distilled water. To correctly use a Colorimeter cuvette, remember:
   - All cuvettes should be wiped clean and dry on the outside with a tissue.
   - Handle cuvettes only by the top edge of the ribbed sides.
   - All solutions should be free of bubbles.
   - Always position the cuvette with its reference mark facing toward the white reference mark at the right of the cuvette slot on the Colorimeter.
6. Calibrate the Colorimeter.
   a. Holding the cuvette by the upper edges, place it in the cuvette slot of the Colorimeter.
   b. If your Colorimeter has an AUTO CAL button, set the wavelength on the Colorimeter to 470 nm (Blue), press the AUTO CAL button, and proceed directly to Step 7. If your Colorimeter does not have an AUTO CAL button, continue with this step to calibrate your Colorimeter.

   First Calibration Point

   c. Choose Calibrate from the Experiment menu and then click Perform Now.
   d. Turn the wavelength knob on the Colorimeter to the "0% T" position.
   e. Type "0" in the edit box.
   f. When the displayed voltage reading for Input 1 stabilizes, click Keep.

   Second Calibration Point

   g. Turn the knob of the Colorimeter to the Blue LED position (470 nm).
   h. Type "100" in the edit box.
   i. When the displayed voltage reading for Input 1 stabilizes, click, then click OK.

7. You are now ready to collect absorbance data for the four equilibrium systems and the standard solution.
   a. Click Collect to begin data collection.

b. Empty the water from the cuvette. Rinse it twice with ~1-mL portions of the Test Tube 1 solution.
c. Wipe the outside of the cuvette with a tissue and then place the cuvette in the Colorimeter. After closing the lid, wait for the absorbance value displayed in the Meter window to stabilize. Then click Keep, type "1" (the trial number) in edit box, and press the ENTER key.
d. Discard the cuvette contents as directed by your teacher. Rinse the cuvette twice with the Test Tube 2 solution and fill the cuvette 3/4 full. Follow the Step-c procedure to find the absorbance of this solution. Type "2" in the edit box and press ENTER.
e. Repeat the Step-d procedure to find the absorbance of the solutions in Test Tubes 3, 4, and 5 (the standard solution).
f. From the Table window, record the absorbance values for each of the five trials in your data table.
g. Dispose of all solutions as directed by your instructor.

Processing the Data

1. Write the K_C expression for the reaction in the Data and Calculation table.
2. Calculate the initial concentration of Fe^{3+}, based on the dilution that results from adding KSCN solution and water to the original 0.0020 M $Fe(NO_3)_3$ solution. See Step 2 of the procedure for the volume of each substance used in Trials 1-4. Calculate $[Fe^{3+}]_i$ using the equation:

$$[Fe^{3+}]_i = \frac{Fe(NO3)3\ mL}{total\ mL}\ X\ (0.0020\ M)$$

   This should be the same for all four test tubes.
3. Calculate the initial concentration of SCN^-, based on its dilution by $Fe(NO_3)_3$ and water:

$$[SCN^-]_i = \frac{KSCN\ mL}{total\ mL}\ X\ (0.0020\ M)$$

   In Test Tube 1, $[SCN^-]_i$ = (2 mL / 10 mL)(.0020 M) = .00040 M. Calculate this for the other three test tubes.
4. $[FeSCN^{2+}]_{eq}$ is calculated using the formula:

$$[FeSCN^{2+}]_{eq} = \frac{A_{eq}}{A_{std}}\ X\ [FeSCN^{2+}]_{std}$$

   where A_{eq} and A_{std} are the absorbance values for the equilibrium and standard test tubes, respectively, and $[FeSCN^{2+}]_{std}$ = (1/10)(0.0020) = 0.00020 M. Calculate $[FeSCN^{2+}]_{eq}$ for each of the four trials.

5. $[Fe^{3+}]_{eq}$: Calculate the concentration of Fe^{3+} at equilibrium for Trials 1-4 using the equation:

$$[Fe^{3+}]_{eq} = [Fe^{3+}]_i - [FeSCN^{2+}]_{eq}$$

6. $[SCN^-]_{eq}$: Calculate the concentration of SCN^- at equilibrium for Trials 1-4 using the equation:

$$[SCN^-]_{eq} = [SCN^-]_i - [FeSCN^{2+}]_{eq}$$

7. Calculate K_C for Trials 1-4. Be sure to show the K_C expression and the values substituted in for each of these calculations.
8. Using your four calculated K_C values, determine an average value for K_C. How constant were your K_C values?

DATA AND CALCULATIONS

Absorbance	Trial 1 _____	Trial 2 _____	Trial 3 _____	Trial 4 _____
Absorbance of standard (Trial 5) _____		Temperature _____ °C		

K_c expression K_c =				
$[Fe^{3+}]_i$				
$[SCN^-]_i$				
$[FeSCN^{2+}]_{eq}$				
$[Fe^{3+}]_{eq}$				
$[SCN^-]_{eq}$				
K_c value				
Average of K_c values K_C = _____ at _____°C				

LESSON PLAN THREE

Determining the Concentration of a Solution: Beer's Law

Objectives

Students will:

- Determine the association between absorbance and concentration as it relates to Beer's Law.

The primary objective of this experiment is to determine the concentration of an unknown nickel (II) sulfate solution. You will be using the Colorimeter shown in Figure 1. In this device, red light from the LED light source will pass through the solution and strike a photocell. The $NiSO_4$ solution used in this experiment has a deep green color. A higher concentration of the colored solution absorbs more light (and transmits less) than a solution of lower concentration. The Colorimeter monitors the light received by the photocell as either an *absorbance* or a *percent transmittance* value.

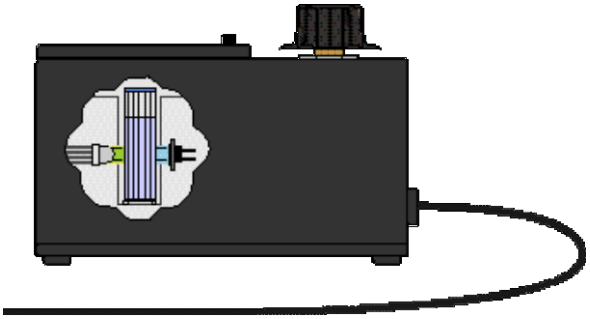


Figure 1

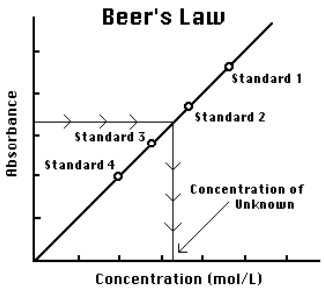


Figure 2

You are to prepare five nickel sulfate solutions of known concentration (standard solutions). Each is transferred to a small, rectangular cuvette that is placed into the Colorimeter. The amount of light that penetrates the solution and strikes the photocell is used to compute the absorbance of each solution. When a graph of absorbance vs. concentration is plotted for the standard solutions, a direct relationship should result, as shown in Figure 2. The direct relationship between absorbance and concentration for a solution is known as Beer's law.

The concentration of an *unknown* $NiSO_4$ solution is then determined by measuring its absorbance with the Colorimeter. By locating the absorbance of the unknown on the vertical axis of the graph, the corresponding concentration can be found on the horizontal axis (follow the arrows in Figure 2). The concentration of the unknown can also be found using the slope of the Beer's law curve.

Materials

Power Macintosh or Windows PC
Vernier computer interface
Logger*Pro*
Vernier Colorimeter
one cuvette
five 20 x 150 mm test tubes
tissues (preferably lint-free)
stirring rod
30 mL of 0.40 M $NiSO_4$
5 mL of $NiSO_4$ unknown solution
two 10-mL pipets (or graduated cylinders)
pipet pump or pipet bulb
distilled water
test tube rack
two 100-mL beakers

Procedure

1. Obtain and wear goggles! **CAUTION:** Be careful not to ingest any $NiSO_4$ solution or spill any on your skin. Inform your teacher immediately in the event of an accident.
2. Add about 30 mL of 0.40 M $NiSO_4$ stock solution to a 100-mL beaker. Add about 30 mL of distilled water to another 100-mL beaker.
3. Label four clean, dry, test tubes 1-4 (the fifth solution is the beaker of 0.40 M $NiSO_4$). Pipet 2, 4, 6, and 8 mL of 0.40 M $NiSO_4$ solution into Test Tubes 1-4, respectively. With a second pipet, deliver 8, 6, 4, and 2 mL of distilled water into Test Tubes 1-4, respectively. *Thoroughly* mix each solution with a stirring rod. Clean and dry the stirring rod between stirrings. Keep the remaining 0.40 M $NiSO_4$ in the 100-mL beaker to use in the fifth trial. Volumes and concentrations for the trials are summarized below:

Trial number	0.40 M $NiSO_4$ (mL)	Distilled H_2O (mL)	Concentration (M)
1	2	8	0.08
2	4	6	0.16
3	6	4	0.24
4	8	2	0.32
5	~10	0	0.40

4. Open the file "Exp 11 Colorimeter" in the Experiment 11 folder of *Chemistry with Computers*. The vertical axis has absorbance scaled from 0 to 0.6. The horizontal axis has concentration scaled from 0 to 0.5 mol/L.
5. You are now ready to calibrate the Colorimeter. Prepare a *blank* by filling a cuvette 3/4 full with distilled water. To correctly use a Colorimeter cuvette, remember:
   - All cuvettes should be wiped clean and dry on the outside with a tissue.
   - Handle cuvettes only by the top edge of the ribbed sides.
   - All solutions should be free of bubbles.
   - Always position the cuvette with its reference mark facing toward the white reference mark at the right of the cuvette slot on the Colorimeter.

6. Calibrate the Colorimeter.
   a. Holding the cuvette by the upper edges, place it in the cuvette slot of the Colorimeter.
   b. If your Colorimeter has an AUTO CAL button, set the wavelength on the Colorimeter to 635 nm (Red), press the AUTO CAL button, and proceed directly to Step 7. If your Colorimeter does not have an AUTO CAL button, continue with this step to calibrate your Colorimeter.

   First Calibration Point

   c. Choose Calibrate from the Experiment menu and then click Perform Now.
   d. Turn the wavelength knob on the Colorimeter to the "0% T" position.
   e. Type "0" in the edit box.
   f. When the displayed voltage reading for Input 1 stabilizes, click Keep.

   Second Calibration Point

   g. Turn the knob of the Colorimeter to the Red LED position (635 nm).
   h. Type "100" in the edit box.
   i. When the displayed voltage reading for Input 1 stabilizes, click Keep, then click OK.
7. You are now ready to collect absorbance data for the five standard solutions. Click Collect. Empty the water from the cuvette. Using the solution in Test Tube 1, rinse the cuvette twice with ~1-mL amounts and then fill it 3/4 full. Wipe the outside with a tissue and place it in the Colorimeter. After closing the lid, wait for the absorbance value to stabilize. Then click Keep, type "0.080" in the edit box, and press the ENTER key. The data pair you just collected should now be plotted on the graph.
8. Discard the cuvette contents as directed by your teacher. Rinse the cuvette twice with the Test Tube 2 solution, 0.16 M $NiSO_4$, and fill the cuvette 3/4 full. Wipe the outside, place it in the Colorimeter, and close the lid. When the absorbance value stabilizes, click Keep, type "0.16" in the edit box, and press the ENTER key.
9. Repeat the Step 8 procedure to save and plot the absorbance and concentration values of the solutions in Test Tube 3 (0.24 M) and Test Tube 4 (0.32 M), as well as the stock 0.40 M $NiSO_4$. Wait until Step 12 to do the unknown. When you have finished with the 0.40 M $NiSO_4$ solution, click Stop.
10. In your Data and Calculations table, record the absorbance and concentration data pairs that are displayed in the Table window.
11. Examine the graph of absorbance *vs.* concentration. To see if the curve represents a direct relationship between these two variables, click the Linear Regression button, R². A best-fit linear regression line will be shown for your five data points. This line should pass near or through the data points *and* the origin of the graph. (Note: Another option is to choose Curve Fit from the Analyze menu, and then select Proportional. The Proportional fit (y = Ax) has a y-intercept value equal to 0; therefore, this regression line will always pass through the origin of the graph).
12. Obtain about 5 mL of the unknown $NiSO_4$ in another clean, dry, test tube. Record the number of the unknown in the Data and Calculations table. Rinse the cuvette twice with the unknown solution and fill it about 3/4 full. Wipe the outside of the cuvette, place it into the Colorimeter, and close the lid. Read the absorbance value displayed

in the Meter window. (**Important**: The reading in the Meter window is live, so it is not necessary to click Collect to read the absorbance value.) When the displayed absorbance value stabilizes, record its value in Trial 6 of the Data and Calculations table.

13. Discard the solutions as directed by your teacher. Proceed directly to Steps 1 and 2 of Processing the Data.

Processing the Data

1. Use the following method to determine the unknown concentration. With the linear regression curve still displayed on your graph, choose Interpolate from the Analyze menu. A vertical cursor now appears on the graph. The cursor's x and y coordinates are displayed at the bottom of the floating box (x is concentration and y is absorbance). Move the cursor along the regression line until the absorbance (y) value is approximately the same as the absorbance value you recorded in Step 12. The corresponding x value is the concentration of the unknown solution, in mol/L.
2. Print a graph of absorbance *vs.* concentration, with a regression line and interpolated unknown concentration displayed. Print a copy of the Graph window. Enter your name(s) and the number of copies of the graph you want.

Data and Calculations

Trial	Concentration (mol/L)	Absorbance
1	0.080	
2	0.16	
3	0.24	
4	0.32	
5	0.40	
6	Unknown number ____	

Concentration of unknown	mol/L

ANNOTATED BIBLIOGRAPHY

Teacher Resources

Champe, Pamela and Richard A Harvey. *Lippincott's Illustrated Reviews: Biochemistry*. 2d ed. Philadelphia: Lippincott, 1994. pp. 229-42.
College-level biochemistry study guide with illustrations. This study guide contains thirty-three chapters (Amino Acids to Molecular Basis of Inherited Diseases) organized into seven units (Protein Structure and Function to Storage and Expression of Genetic Information). This study guide is an excellent resource for learning biochemistry for the visual learner; every page contains several annotated illustrations pertinent to the concepts presented.

Holmquist, Dan, et al., eds. *Chemistry with Calculators*. 3d ed. Oregon: Vernier Software & Technology, 2000. pp. 11-1 to 11-4, 20-1 to 20-5.
High school level Texas Instrument calculator-based chemistry experiment manual. This manual has thirty-six chemistry experiments using the six probes (Temperature; Voltage; Conductivity) and sensors (Gas pressure; pH; Colorimeter). This lab manual is designed to instruct students on how to use the TI-83 (science) graphing calculator to collect and manipulate data obtained from chemistry experiments. This manual provides instructions on how to manipulate mathematically.

Stryer, Lubert, *Biochemistry*. 4th ed. New York: W.H. Freeman and Company, 1995. pp. 181-206, 713-37.
Graduate level biochemistry textbook. This textbook extensive covers the principles of biochemistry. This textbook contains thirty-seven chapters covering Protein Structure and Function to Eukaryotic Chromosomes and Gene Expression. These chapters are organized into five parts beginning with "Molecular Design of Life" and ending with "Genes: Replication and Expression." This textbook is ideal when detailed factual information is required.

Webb, L. Dean, et al., eds. *Foundations of American Education*. 3d ed. New Jersey: Prentice-Hall, 2002. pp 317-36.
College level textbook: This textbook focuses on instructing students preparing to teach in the primary and secondary school settings. This textbook contains sixteen chapters organized into seven parts. The chapters cover all aspects of teaching such as the "Status of the Profession to Education for the New Millennium."

Student Resources

Davis, Raymond. *Modern Chemistry*. Austin: Holt, Rinehart and Winston, 2002. pp. 508-51.

High school level chemistry textbook. This textbook contains twenty-two chapters organized into seven units beginning with "Introduction to Chemistry and Matter" and ending with "Organic and Nuclear Chemistry." This is a good textbook for preparing high school for college level chemistry courses. This textbook has a chemistry interactive tutor CD-ROM instructional disk for the students.

Gilbert, Hiram F. *Basic Concepts in Biochemistry: A Student's Survival Guide*. New York: McGraw-Hill, 1992. pp. 66-78.

College level biochemistry study guide. This study guide focuses on teaching the basics of biochemistry. This study guide contains twenty-two chapters (Protein Structure to Thermodynamics and Kinetics) designed to provide the fundamentals of biochemistry. This study guide does not provide some visual illustrations but not as many as the Lippincott Illustrated Biochemistry Review listed above.

Wilbraham, Anthony, et al., eds. *Chemistry*. Massachusetts: Prentice-Hall, 2002. pp. 532-76.

High school level chemistry textbook. This textbook contains twenty-eight chapters (Introduction to Chemistry to Nuclear Chemistry). This is an excellent textbook for preparing high school for college level chemistry courses. Chem ASAP CD-ROM is available with this book; this CD-ROM is an interactive CD designed to teach chemistry visually.

Internet Resources

www.vernier.com

Vernier Software & Technology

This website is the online support for the Vernier Company. Vernier supplies laboratory books, software, peripherals, probes, and sensors for the TI-83 (science) Graphing Calculator and the Palm Handheld PDA like Palm Pilot and Visor. This site has several sections concerning workshops, downloads, products, and news.

http://com.houstonisd.org/hulinc/

Houston Urban-Learning Initiatives in a Networked Community (HU-LINC)

This website is the online support for the HU-LINC teachers in the Houston Independent School District (HISD). Information concerning the HU-LINC origins, goals, programs, professionals, other related topics, and various pertinent links are present.

www.ti.com/calc
Texas Instrument

This website is the online support for the Texas Instrument calculators. Extensive information involving the TI-graphing calculators, guidebooks for the each calculator (in various languages), downloads, CBLs, probes/sensors, discussion groups, support, and other miscellaneous topics.

www.flinnsci.com
Flinn Scientific, Inc.

This website is the online support for the Flinn Scientific, Inc. This site is an excellent site for high school science teachers; it is a virtual cornucopia of educational science links. Flinn scientific products and services are advertised along with opportunities to join their company.